LESSON 20 - REVIEW OF ELECTROMAGNETISM
Understanding the propagation of electromagnetic (EM) waves is essential to understanding radar. Knowing how to analyze these waves makes understanding more advanced concepts much easier.

Reading:
　　　Stimson **Ch. 4, Ch.6**
Problems/Questions:
　　　Work on Problem Set 3
Objectives:
　　　20-1　Understand how EM waves are produced.
　　　20-2　Understand how Maxwell's Equations in a vacuum predict EM waves.
　　　20-3　Know the different variables associated with the wave equation and what they stand for.
　　　20-4　Know the definition of a decibel.
　　　20-5　Understand how to use the decibel to show relative intensity.

Last Time:　Radar as a way to get to (or avoid) the visual BFM engagement
　　　　　　Information provided by a radar
　　　　　　Radar Components

Today:　　　E&M review
　　　　　　Waves/introduction to phasors

Review Maxwell's equations

$$1. \oint \vec{E} \bullet d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \qquad\qquad 2. \oint \vec{B} \bullet d\vec{A} = 0$$

$$3. \oint \vec{E} \bullet d\vec{s} = -\frac{d\Phi_B}{dt} \qquad\qquad 4. \oint \vec{B} \bullet d\vec{s} = \mu_0 I + \varepsilon_0 \mu_0 \frac{d\Phi_E}{dt}$$

Assume free space => q=0 and I=0

1 and 2 say there are no sources of charge or magnets in the area
3 says E is related to a time changing B.
4 says B is related to a time changing E.

If we substitute 3 into 4 or vice versa, we get equations of the form
$\frac{d^2E}{dx^2} = \varepsilon_0\mu_0\frac{d^2E}{dt^2}$. This is a high-falutin' bunch of math that describes a
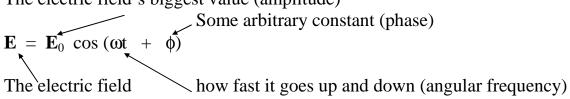*traveling wave*.

Any function whose second spatial derivative equals 1/v times its second time derivative is a traveling wave.

Another result is that a simple dimensional analysis says that $\frac{1}{\sqrt{\varepsilon_0\mu_0}}$ has

units of velocity, and the magnitude of this quantity is 3×10^8 m/sec, or the speed of light. (in SI, $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2/N-m^2 and $\mu_0=4\pi \times 10^{-7}$ N/A)

You may be more familiar with the wave equation from 215 in the usual sinusoidal functions as $y = A(\cos(\omega t + \phi))$, where y can be either **E** or **B**. and A is either E_0 or B_0, respectively.

More specifically,

The electric field's biggest value (amplitude)
                                                    Some arbitrary constant (phase)

$\mathbf{E} = \mathbf{E}_0 \cos (\omega t + \phi)$

The electric field   how fast it goes up and down (angular frequency)
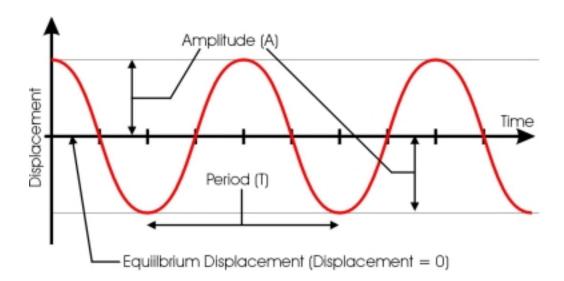
OR

The magnetic field's biggest value (amplitude)
                                how fast it goes up and down (angular frequency)

$\mathbf{B} = \mathbf{B}_0 \cos (kx - \omega t)$

The magnetic field   a constant related to 1/wavelength (wave number)

Show that these equations are waves by differentiation.

You should be able to identify the following things on a graph of a wave: amplitude, wavelength, period, and phase; be able to tell if the wave is a cosine wave or a sine wave; given a graph of a wave, be able to calculate the frequency, angular frequency, and wave number of the wave.

Note that the above figure has time on the horizontal axis. If the axis were position (x), then the distance labeled "Period" would instead be the wavelength, λ.

Show "wave amplitude.avi", "wave frequency.avi", and "wave phase.avi"

With all of that said, what do we really need to know?

$\omega = 2\pi f$ $c = \lambda f$

So, since v = fixed for all EM waves = c, knowing f, we also know λ and vice versa.

What does this all mean? I thought we were being tactical here?

Patience, grasshopper. You must know the alphabet before you can study Hamlet. We need this very rudimentary electromagnetic background before we can see why radars behave the way they do; knowing how they behave will allow us to use our radars and figure out ways to keep the enemy from using theirs. And that's a *very* tactical motivation.

Assume we have an electron in a wire traveling at a constant velocity. As it moves, E varies with time, so we have a built-in dE/dt. But B is proportional to v, so at a constant v, B is constant, so dB/dt =0, and no E is induced.

But if the charge accelerates, things are very different. E = E(t) ≠ 0; B = B(t) ≠ 0 => self propagating wave. dE/dt => dB/dt => dE/dt …

Show Mechanical Universe, 39, frame 41174.

If electrons move back and forth in a sinusoid, they're always accelerating, so they're always making E&M waves.

Sinusoidal motion can be modeled by vertical simple harmonic motion.

Show Mechanical Universe 16, frame 26813.

Spinning bicycle wheel with tape demo; talk about phase.

Recommend Chapter 4 of Hughes as a VERY good, quick review of E&M.

Explain that dB will not be covered in class very much, but is important and WILL be tested.

The formula that you will need to know about dB is used to convert from a power ratio to dB and back again.

Power ratio in decibels = $10\log_{10}\left(\dfrac{P_2}{P_1}\right)$

Thus, if you know that the power you get back from your radar signal is 100 times weaker than the power you sent out, $P_2 = 0.01$ and $P_1 = 1$. Plugging these numbers into the formula, then we say the received signal is *down 20dB*, or is *-20dB from*, the transmitted signal. Notice that this is just ten times the exponent of the ratio (the ratio is 0.01, or 10^{-2}).

An important dB ratio to know is where the power of one signal is twice that of another signal. This makes our ratio 2, and plugging into the formula, you can see that this power ratio is almost exactly **3dB**. We'll use 3dB *a lot* as a fancy way of saying the power ratio between two signals is 2.

STRONGLY emphasize that they NEED to read Hughes, Chapter 5 if they expect to understand the rest of the course. The whole book and all the lectures speak in terms of phase diagrams and phasors.